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Plant Cover Establishment Methods on a Severe Rocky Mountain Foothills Site

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S.K. Takyi

1984
Edmonton

ENERGY AND
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PLANT COVER ESTABLISHMENT METHODS ON A SEVERE ROCKY MOUNTAIN FOOTHILLS SITES[1]

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INTRODUCTION

The major causes of drastic land disturbances in the alpine and subalpine areas of Alberta are surface mining, oil and gas well development, pipeline construction and the access infrastructures which service installations and bring the resources to markets. Some forestry operations also involve drastic land disturbances. With continuing demands for natural resources, activities leading to land disturbances will continue. The disturbance rate may be accelerated in the next few decades. Although there have been good examples of successful reclamation in the subalpine and alpine areas, there are several examples of failure in very critical areas, which, if they had received the appropriate reclamation treatments, could have had greater chance of reclamation success. High elevation areas play a vital role in our watershed and recreational resources, which should be given the same importance accorded wildlife and forestry resources in these areas.

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[1] A paper presented at the Workshop on Revegetation Methods in the Mountains and Foothills. April 30 and May 1, 1984, Edmonton, Alberta, Canada.

Critical areas which are difficult to stabilize and revegetate in the high elevation zones in Alberta include steep slopes and road cuts and spoil piles, disturbed wind-swept areas, approaches to stream and creek crossings, and areas of poor soil materials requiring special treatments. In many cases in these high-elevation disturbances, the establishment of a plant cover can be achieved with the same revegetation principles and techniques employed in ecosystems with a much less harsh plant-growth environment. The role played by the less than hospitable plant-growth environment in the high-elevation areas cannot be over-emphasized. For what might seem to be similar site conditions on disturbed sites in a low elevation ecosystem and a high elevation ecosystem, reclamation problems could be magnified severalfold in the latter. Because of the harsh environment in the high elevation sites, these critical areas pose even greater problems and should therefore be given greater attention in terms of employing more reliable reclamation techniques. Never has the need for the development and implementation of suitable reclamation techniques for critical problem sites in disturbed high-elevation areas become more apparent than now, because of resource-extraction development which may be forthcoming in the next few decades. It means we should acquire the technology now to be able to restore land-surface stability, aesthetic compatibility and even productivity to high-elevation disturbances once we have removed the needed resources.

For such high-elevation environments, successful revegetation can most often be ensured if the physical environment is modified to meet as closely as possible the growth requirement of the selected plant species, native or introduced. Once the physical environment has been modified, the most critical problem is the adaptability of the selected species to the harsh climate. As indicated earlier, there has been considerable industrial activity in the high-elevation areas; unfortunately, reclamation of the critical areas has not always been successful primarily because the development and the implementation of suitable techniques have not kept pace with industrial activity. Observations of the situation confirm that specific reclamation techniques should be employed to handle site specific problems. For some time now there has been interest in Alberta in undertaking research into revegetation of land disturbances, primarily mining disturbances, to enhance reclamation success. The two experiments I will be discussing were started in 1979 and 1980 in an effort to find solutions to some revegetation problems, especially in the harsh and critical sites which have been difficult to revegetate.

The objectives of the studies were (a) to assess plant cover establishment success employing different methods of seeding a native grass seed mix on a very coarse and pervious mine overburden, (b) to assess the effect of seeding methods on growth following cover establishment, and (c) to evaluate the use of erosion-control materials and surface manipulation (ridging) as methods for establishing plant cover on a harsh site. I also sought to estimate the magnitude of erosion in relative terms. In planning these experiments I intended that the methods be practical so the results could be applied to operational reclamation situations. As plant cover is recognized as the important component for determining adequate reclamation of disturbed land, especially in erosion problem situations, its successful establishment was an important objective of the experiments.

STUDY SITE

The two experiments are located on a coal mine abandoned in 1952 near the hamlet of Cadomin, on the Nikanassin Range. There are three operating surface mines and two others being planned within a 40 km radius of this abandoned mine. The elevation of the site is approximately 1 675 m ASL, just below treeline. Treeline in this area is at about 1 980 m ASL, but because of the disturbed and exposed nature of the site brought about by mining, environmental conditions strictly favour subalpine and alpine. Vegetation on the disturbances is very sparse and consists of isolated plants in open communities. The sites lacked any vegetation at the time of the establishment of the experiments. Mining at the site predated the requirement of environmental impact assessment and the current practices of soil stockpiling and selective overburden handling. The current site conditions attest to the lack of environmental planning.

One experiment (methods of erosion control) is located on a west-facing slope of a waste pile consisting of an admixture of sandstone, siltstone, shale overburden and coal fragments. The second experiment (establishment methods of native grasses) is located on a flat-top pile consisting of much larger fragments of the same materials, but it contains no coal. At both experimental sites there is normally hardly any snow accumulation in the winter because of the high winds. The chinook wind common to the area rapidly removes any snow which remains on the sites. Because the chinook wind is so warm and dry the melted snow is vaporized in the winter and early spring and little of it benefits the sites, except for that which falls in late spring (early June). These two very harsh sites failed to regenerate naturally over the 30 years following mine abandonment and for this reason were selected for the experiments.

REVEGETATION METHODS

A. Methods of Erosion Control for Cover Establishment

The experiment was laid out in a randomized block design with four replications of five treatments each in early June, 1979. Treatments consisted of the use of three erosion-control materials, construction of ridges spaced at one-metre intervals across the slope, and a control. The three materials, jute net (Ludlow Soil Saver, Type #48 - heavy mesh), excelsior blanket (AMXCO "Curlex"), and "hold/gro" (the standard seeding type for slopes, ditches, etc.), were applied according to manufacturer specifications. The plots were laid out and ridges constructed where required. Seeding at a rate of 60 kg/ha was carried out by broadcasting, and followed by hand broadcast of fertilizer (600 kg/ha of 10:30:10 - 60 kg N : 78 kg P : 50 kg K/ha). Both fertilizer and seed were raked into all the plots, to be followed by the application of the erosion-controlling materials in the designated plots. Seed mixture used was cultivated varieties of creeping red fescue, Festuca rubra, 40% by weight; white clover, Trifolium repens, 12%; Timothy, Phleum pratense, 24%; and Canada bluegrass, Poa compressa, 24%.

The spoil is rather coarse with more than 70% of the surface materials from 0-15 cm depth being larger than 2 mm in size (Table 1). The porous nature of the spoil coupled with the high prevailing wind renders at least the surface of the spoil droughty during considerable periods in the growing season. The fertility of the spoil is rather low, and it has a high pH (Table 1). Total nitrogen is high and is attributable to the high content of the element in the coal in the spoil (Campbell, J.D. 1970. Alberta Foothills Coal. Extracts from Alberta Research Council Reports).

B. Cover Establishment Methods with Native Grass Mixture

The experiment was established in mid-June, 1980, on a flat overburden pile in a randomized block design with eight treatments in four replications. The treatments consisted of direct seed broadcast (control), simulated drilling, straw (and nylon net) placement over broadcast seed, hydroseeding with wood fibre mulch, hydroseeding with grass mulch, seed broadcast followed by hydromulching, seed broadcast followed by the placing of excelsior blanket, and seed broadcast followed by the placing of hold/gro. (The excelsior blanket and the hold/gro were the same materials described in the previous experiment). The wood fibre mulch was applied at 2 000 kg/ha, the grass mulch at 5 000 kg/ha, and the barley straw at 5 600 kg/ha.

TABLE 1

SOME PROPERTIES OF THE SPOIL

a. CHEMICAL:

pH	EC mS/cm	TOTAL N, %	AVAILABLE NUTRIENTS, ppm				TEC me/100 g
			NH_4^+	NO_3^-	P	K	
8.4	0.2	0.56	1.5	0	1.5	34.0	9.3

b. PARTICLE SIZE DISTRIBUTION:

COARSE FRACTION, % (> 2 mm)	SOIL FRACTION, % (≤ 2 mm)			
	SAND	SILT	CLAY	TOTAL
70.9	19.2	6.1	3.8	29.1
—	66.0[2]	20.8[2]	13.2[2]	—

[1] BULK SAMPLE (EXCLUSIVE OF LARGER STONES AND ROCK FRAGMENTS)

[2] AS A PERCENTAGE OF THE SOIL FRACTION

Seeding rate was 46.1 kg/ha. The seed mixture consisted of the same number of seeds of each of the following four species, each originating from the Rocky Mountains area: slender wheatgrass (4[1]), Agropyron trachycaulum (68.1% by weight); alpine sheep fescue (144[1]), Festuca saximontana (14.5%); alpine bluegrass (153[1]), Poa alpina (9.3%); and interior bluegrass (150[1]), Poa interior (8.1%). In terms of relative seed size based on 1 000 seed weight, the mixture ratio was 8.4 : 1.8 : 1.1 : 1.0 respectively for the species. Fertilizer (10:30:10 at 600 kg/ha) was broadcast and the plots raked before applying the treatments.

The overburden pile on which the experiment was laid out was rather coarse and contained large stones and rock fragments. A mechanical analysis for the soil size component indicated it to be high in sand (Table 2). As with the spoil pile this overburden pile tested high in pH, (Table 2) and the fertility level was very low. Total nitrogen, as expected, was also low.

RESULTS AND DISCUSSION

A. Techniques of Erosion Control in Cover Establishment

The first year gave encouraging results in plant establishment in all five treatments, including the control. Moisture availability in soil plays a significant role towards achieving reclamation success, especially in harsh environments with coarse soils in the study area. Moisture content of the surface 15 cm layer of the spoil under the various treat-

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[1] Selection line number (Genetics Department, University of Alberta - 1978 harvest).

TABLE 2

SOME PROPERTIES OF THE OVERBURDEN

a. CHEMICAL:

pH	EC mS/cm	TOTAL N, %	AVAILABLE NUTRIENTS, ppm					CEC me/100 g
			NH_4^+	NO_3^-	P	K	SO_4 S	
8.5	0.2	0.04	0.7	1.1	0.5	47.5	3.0	7.4

b. PARTICLE SIZE DISTRIBUTION

COARSE FRACTION, % (> 2mm)	SOIL FRACTION, % (≤ 2 mm)			
	SAND	SILT	CLAY	TOTAL
72.4	21.0	4.5	2.1	27.6
—	76.0[2]	16.4[2]	7.6[2]	—

[1] BULK SAMPLE (EXCLUSIVE OF LARGER STONES AND ROCK FRAGMENTS)

[2] AS A PERCENT OF THE SOIL FRACTION

ments, approximately two months after seeding and following relatively-substantial precipitation (31 mm) in the preceding week, was greater under the erosion control materials although the differences were not significant (Figure 1). The lower moisture content in the troughs in comparison with the control is attributable to the competition for moisture by the greater number of germinants per unit area in the troughs (the increased number of germinants is a result of seeds on the ridges having drifted into the troughs). On the other hand, the moisture content in the control suggests that the plant cover minimizes spoil desiccation by radiation and high winds as compared with bare (ridge tops) spoil.

One of the major roles of a mulch is to control excessive evaporation loss of soil moisture, and in this sense the erosion control materials used in the experiments also act as mulches. As biomass production (discussed later) was greater under the materials, the demand for moisture was expected to have been greater, and soil moisture data suggest that the materials acted effectively as mulches. In a harsh environment, especially one with the added limitation of an excessively porous growth medium, the slight increase in soil moisture level that could be obtained with the erosion control materials could mean a success in establishing cover, especially in a year with an excessive number of long, dry periods.

Spoil temperatures at 5 cm depth in the various treatments and in the developed plant cover nine weeks into the experiment during the course of one day are given in Figure 2. No extremely high temperatures were observed on a day when the highest atmospheric temperatures

Figure 1:

MOISTURE CONTENT OF THE SURFACE 15 cm LAYER, TWO MONTHS AFTER TREATMENT

DIFFERENCES NOT STATISTICALLY SIGNIFICANT - 5% DMRT

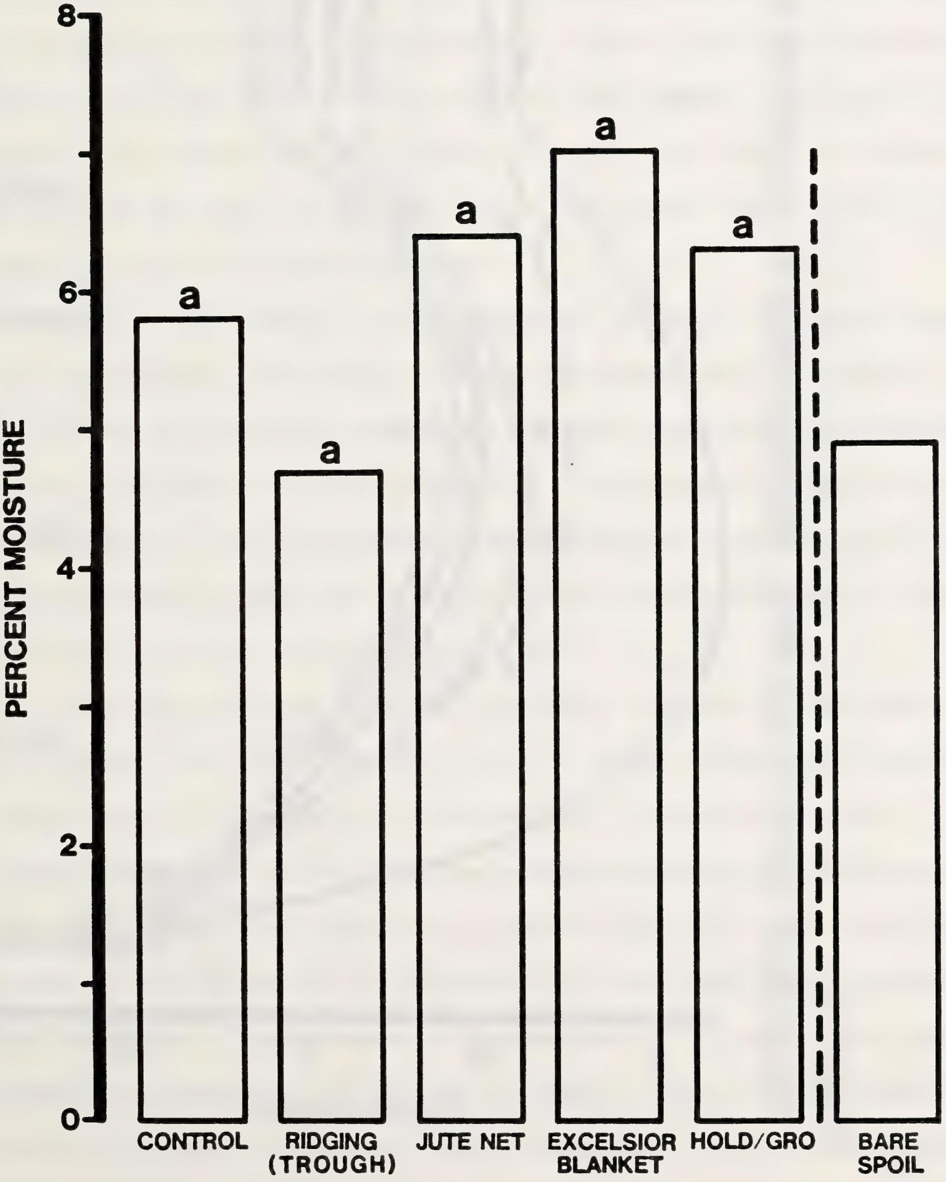
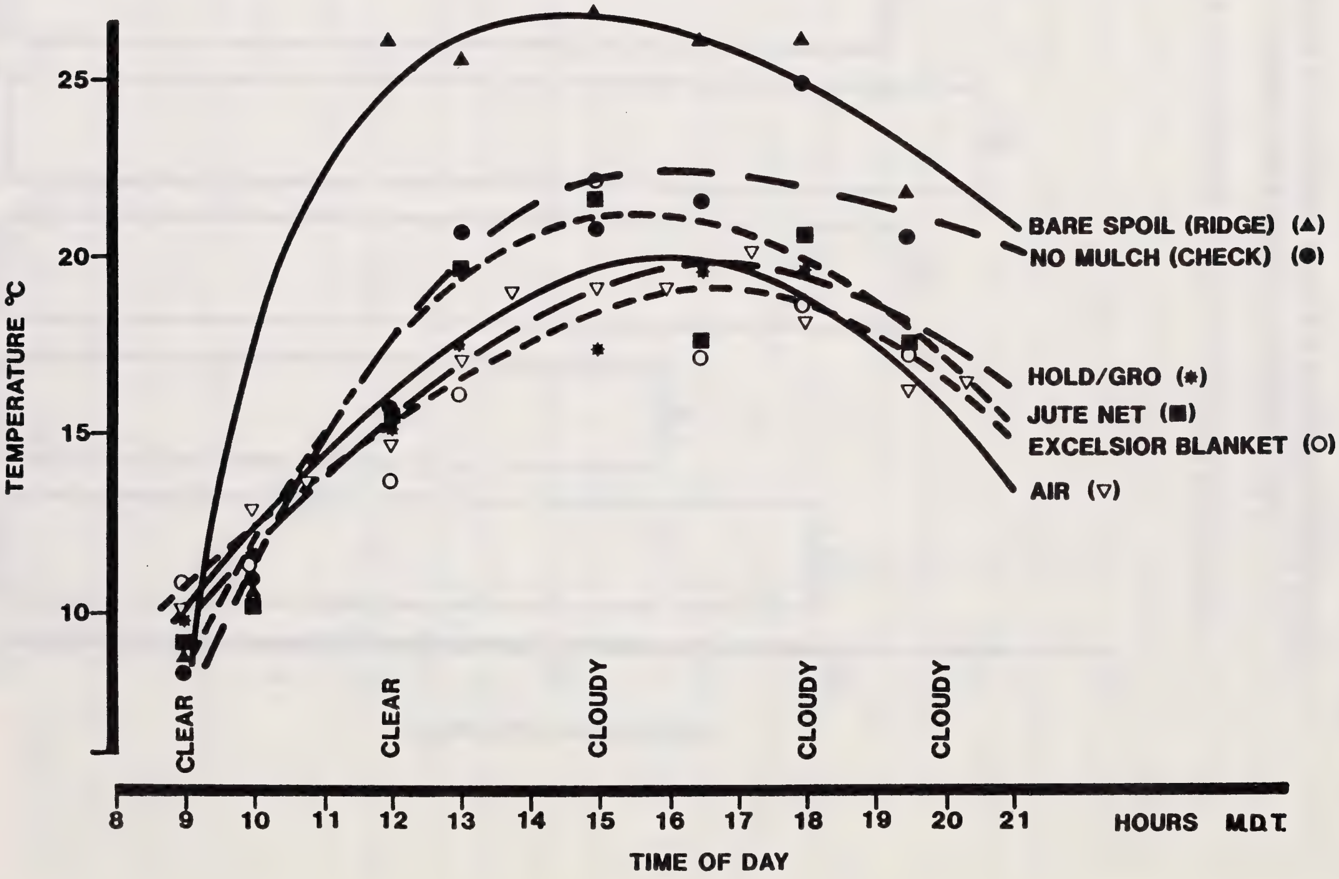


Figure 2:

TREATMENT EFFECTS ON SPOIL TEMPERATURES (5-cm DEPTH) AUGUST 13, 1979



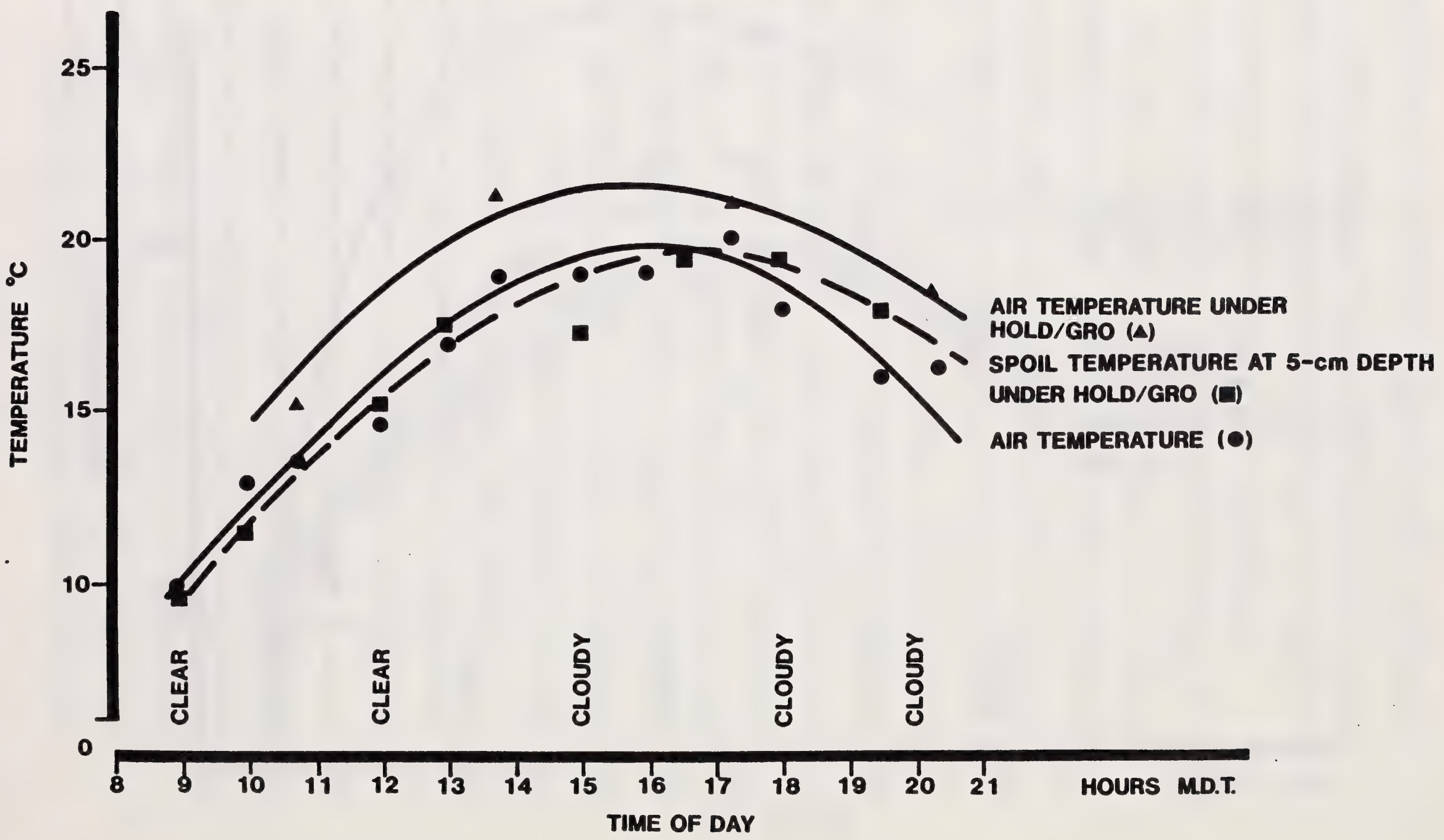
recorded at the site ranged between 18.3° and 23.1°C in a two-hour period (14:55 - 16:55 h). The average temperature was 16.2°C between 08:55 and 19:50 hours and represented a warm day on the site.

Temperatures were generally lower at the 15 cm depth than at the 5 cm depth in all treatments in the measurements made after 12:00 hours except in the excelsior blanket treatment where the earlier afternoon temperatures essentially were the same at both depths (data for 15 cm depth are not illustrated). In general, temperatures under the excelsior blanket and the hold/gro treatments were marginally higher at the 5 cm depth than under the other treatments.

The air temperature in the plant cover, under the hold/gro (which was raised by the plant cover) was slightly higher than the ambient air temperature and the spoil temperature at 15 cm depth under the hold/gro during the course of the day (Figure 3). The situation perhaps created a "green-house micro-environment" effect during some periods and thus promoted better growth, as indicated by the higher percentage of plant cover and dry matter yield (discussed later).

Although the major function of mulches has been in soil moisture conservation, they have also been used in hotter climates to keep the seedbed cooler and to regulate the variations in soil temperatures in the course of the day. In this study the excelsior blanket and hold/gro were effective in keeping the seedbed (5 cm depth) slightly cooler during the warmer periods of the day to the extent that they might have influenced seed emergence. The influence of the mulches in regulating spoil temperatures did not extend to the 15 cm depth. Temperature differences between the bare spoil and the control (with plant cover) indicated some

Figure 3: HOLD/GRO EFFECTS ON TEMPERATURES - AUGUST 13, 1979



moderating influence of the plant cover on the fluctuations in spoil temperature. Spoil temperature data collected in the mid-morning clearly suggests that the temperatures in the spoil under the hold/gro and excelsior blanket probably do not fall as much overnight as in the other treatments. This perhaps indicates that in this environment (cool, and Foothills region), seed emergence may be earlier under these two roll-out mulches. Observations on the progress in plant growth early in the season indicated that this could have been the case.

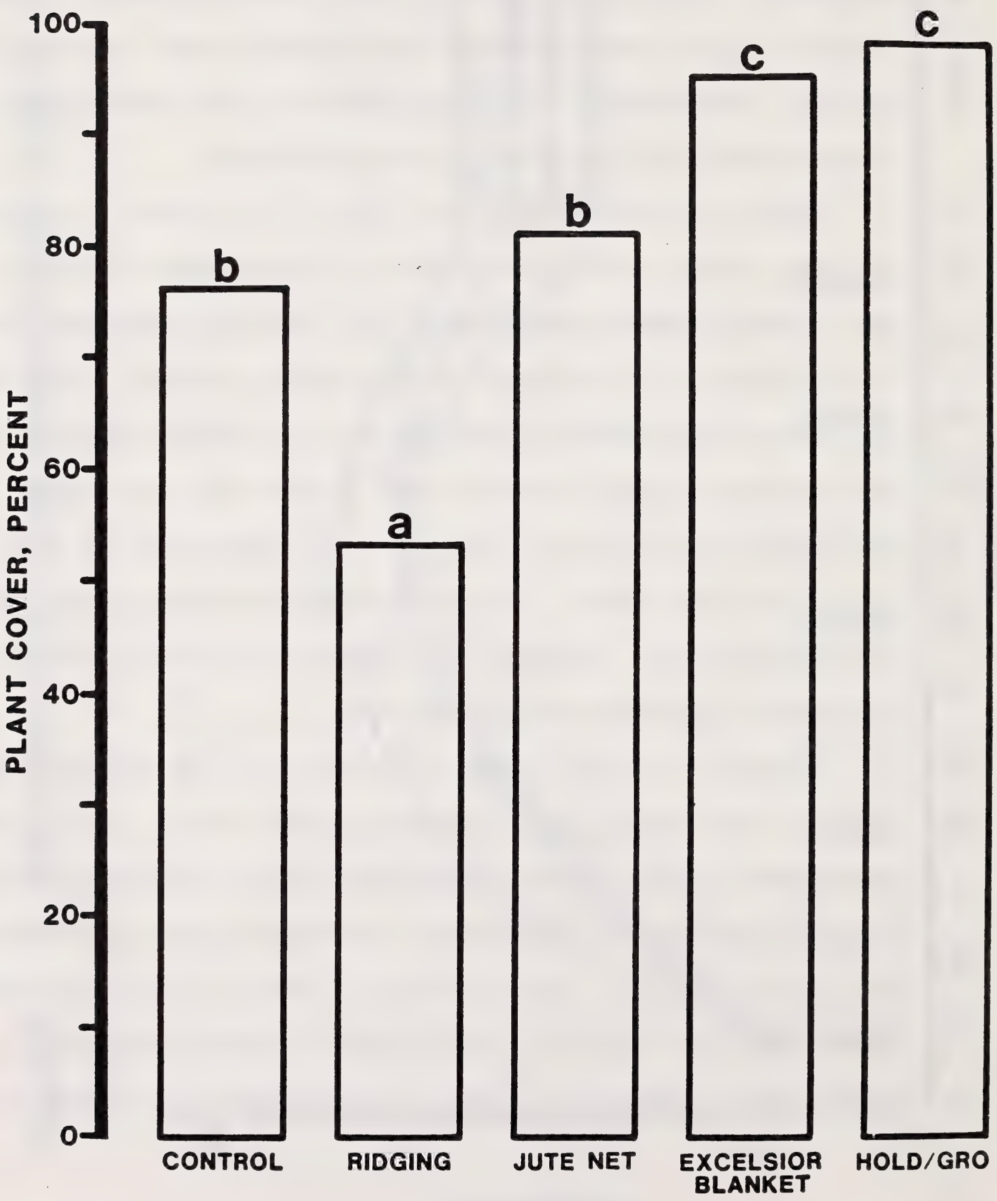
Plant cover percentages were high in all treatments at the end of the first growing season, considering the plant growth limitations of the site. Hold/gro and excelsior blanket gave the highest percentage of plant cover (Figure 4). Percentage of plant cover increased substantially in the second season with the exception of the hold/gro treatment, which had produced an almost complete plant cover in the first season. Cover was maintained at as high a level in each treatment in the third (1981) season as in the second. Cover decreased somewhat in 1982, the first year fertilizers were withdrawn, and showed substantial decrease in each treatment in the subsequent (1983) year.

Figure 4 indicates cover to be lowest in the ridging treatment, because while plants grew actively in the trough, there was little encroachment onto the crest. With time, however, the ridges are beginning to flatten out and plant cover has started slowly encroaching upon the flattened ridges. Cover within the plots has not encroached the unseeded borders between plots although the plants are producing viable seeds. This implies that in order to obtain plant cover on the abandoned

Figure 4:

PLANT COVER TWO SEASONS (1980) AFTER SEEDING

SAME LETTERS INDICATE NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.



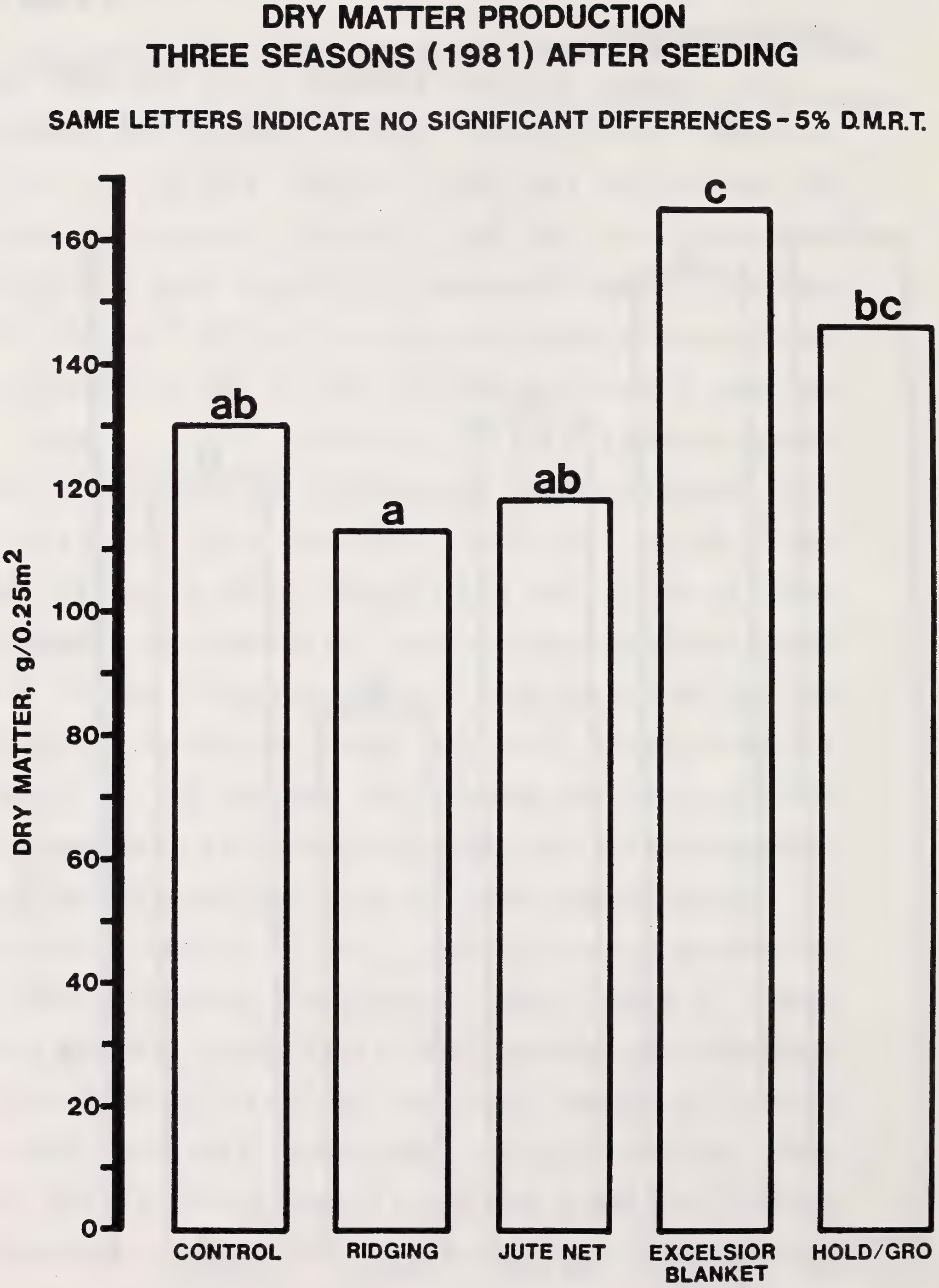
mine nature needs assistance, especially in spoil-surface manipulation to anchor these seeds.

As expected, dry matter production in the first season was low; considering the environment, however, production was acceptable, as was the case with plant cover. Hold/gro gave the best dry matter production in the first year. While the experiment was fertilized, production increased substantially in the second season in all treatments, and the same high levels were continued into 1981 (Figure 5). Production began to show some decline in 1983, the year after fertilization was stopped (data for 1982 and 1983 not shown).

Production was more than doubled in the second year and remained high in the third year under the excelsior blanket and jute net treatments, as was the case in the control. Although hold/gro gave the highest production in the first year, the increase in the subsequent year was low; however the level of production remained high in the second and third years. There were clearly no significant differences in production under the erosion-control materials, and the jute net was much more effective than ridging or the control in the subsequent years.

During the first year, the plants could not effectively penetrate the hold/gro and grow above it. This did not seem to have affected growth; it rather created a "greenhouse micro-environment" which explains the high production level in the treatment. The high production levels in the excelsior blanket and the hold/gro are attributable to the higher spoil moisture status. Since the tops of the ridges in the ridging treatment were free of plant cover, the high production in this treatment since the second year is also due primarily to the moisture status in the troughs.

Figure 5:


DRY MATTER PRODUCTION
THREE SEASONS (1981) AFTER SEEDING
SAME LETTERS INDICATE NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.
DRY MATTER, g/0.25m²
160
140
120
100
80
60
40
20
0
ab
a
ab
c
bc
CONTROL
RIDGING
JUTE NET
EXCELSIOR BLANKET
HOLD/GRO

The extent of erosion in the plots would depend on the amount and intensity of rainfall. We were able only to measure the total precipitation over given periods. Total precipitation was low during the germination and cover establishment phase of the study (Table 3), resulting in a lesser degree of surface run-off; hence few erosion problems occurred. Most of the precipitation (62%) occurred in the last third of the season.

There was hardly any erosion in the excelsior blanket and hold/gro treatments in the first season (Figure 6); however, in some of the plots, the hold/gro and the plant cover under it were subjected to burying by spoil which was moved downslope by flowing water originating outside the plots. Erosion in the jute net treatment was minimal, but some burying occurred, as with the hold/gro. Thus none of the roll-out mats, with the possible exception of the excelsior blanket, could be considered effective in stopping spoil material, which was carried in flowing water originating elsewhere on the slope, from burying the establishing plant cover. Erosion in the ridging treatment was minimal; here, however, the spoil which was eroded from the sides of the ridges buried portions of plant cover in the troughs. In one replication, gully erosion originating outside the experiment area filled the first trough with spoil and overflowed it, and the gully subsequently continued through the plot. Most, and probably all of the 36 mm of precipitation (Table 3) recorded between August 21 and 27, 1979, occurred on August 25, perhaps all of it occurring within two hours. Minor sheet erosion, minor gullying, and severe rill erosion on the slope on which the experiment was located suggests that the precipitation received that day

TABLE 3

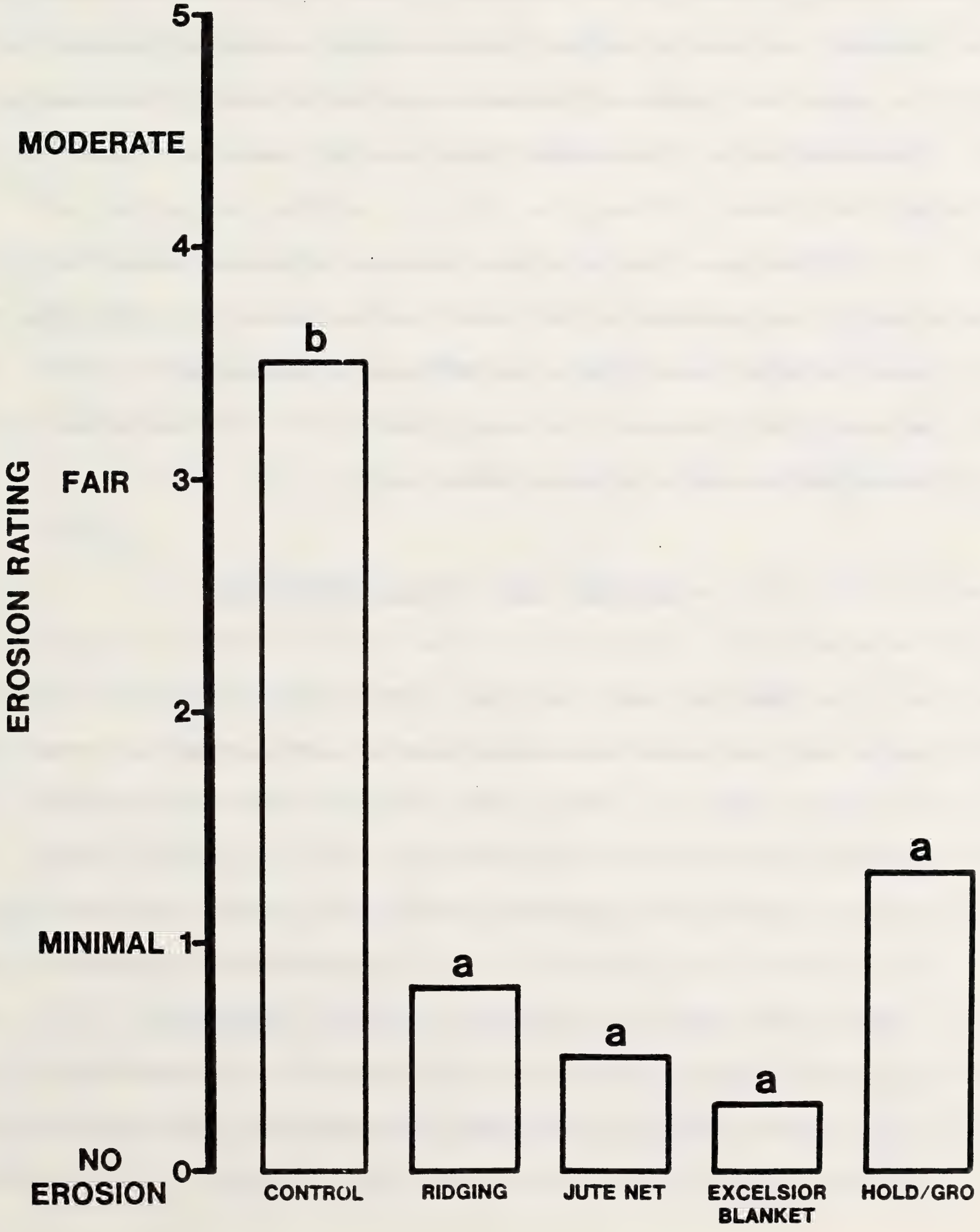
PRECIPITATION (mm) IN THE FIRST SEASON OF GROWTH

	NO. OF DAYS AFTER SEEDING								
	1	9	27	35	54	61	67	75	81
TOTAL, BETWEEN MEASUREMENTS	9	6	21	14	29	31	3	44	36
MEAN DAILY, BETWEEN MEASUREMENTS	9.00	.75	1.17	1.75	1.52	4.43	.50	5.50	6.00
ACCUMULATIVE	9	15	36	50	69	100	103	147	183
% MOISTURE CONTENT (BARE SPOIL)	8.8	—	3.6	—	—	4.9	—	3.4	—

Figure 6:

EROSION RATINGS THREE SEASONS (1981) AFTER TREATMENT
OCULAR RATING: 0 (NO EROSION) TO 9 (VERY SEVERE EROSION)

SAME LETTERS INDICATE NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.



was of high intensity. In the long term, the excelsior blanket and the jute net were best in controlling erosion (Figure 6).

The observation for this abandoned mine on which the piles have remained relatively stable for many years is that any erosion is storm induced and that for a given season a single storm could account for all the significant erosion. Because snow cover is virtually non-existent on the experimental site, erosion associated with snowmelt run-off on the pile is minimal.

There are other aspects of the experiment such as differences in fertility and nutrient levels in the plant materials on which data have been collected, especially since fertilization was stopped in 1982. Time allotted for this paper allows primarily for the discussion of the revegetation aspects of the experiment.

B. Native Grass Cover Establishment

In the trial involving plant cover establishment on an extremely harsh site with a seed mixture composed of native grasses of considerable seed-size differences, the results indicate that seed emergence is a significant factor to be considered in the choice of a seeding method. Our experience with native grasses in other trials on two abandoned mines in the foothills showed that with native grasses there is virtually no plant cover establishment to be expected in the first season. In the first season, germination for some grass species was not complete. In this trial, plant cover was essentially non-existent as germination was not complete and the germinants were still tiny at the end of the first season.

Because of the types of treatment in the trial, germinant count was not possible but a germination rating revealed considerable differences due to treatments (Figure 7). Germination was best in the excelsior blanket treatment, closely followed by simulated-drilling and in a distant second place by treatments involving seed broadcasts with the placement of a protective cover of hold/gro, straw or wood fibre hydromulch. Hydroseeding with grass mulch or wood fibre mulch, or seed broadcast gave low germination ratings. It was not possible to rate the degree of germination under the straw as most germinants were still under it. The Agropyron was observed to have the highest degree of germination. Early in the second season (Figure 7) the germinants in the excelsior blanket and straw treatments began to be more conspicuous, and the germination in the excelsior blanket rated even better than in simulated drilling.

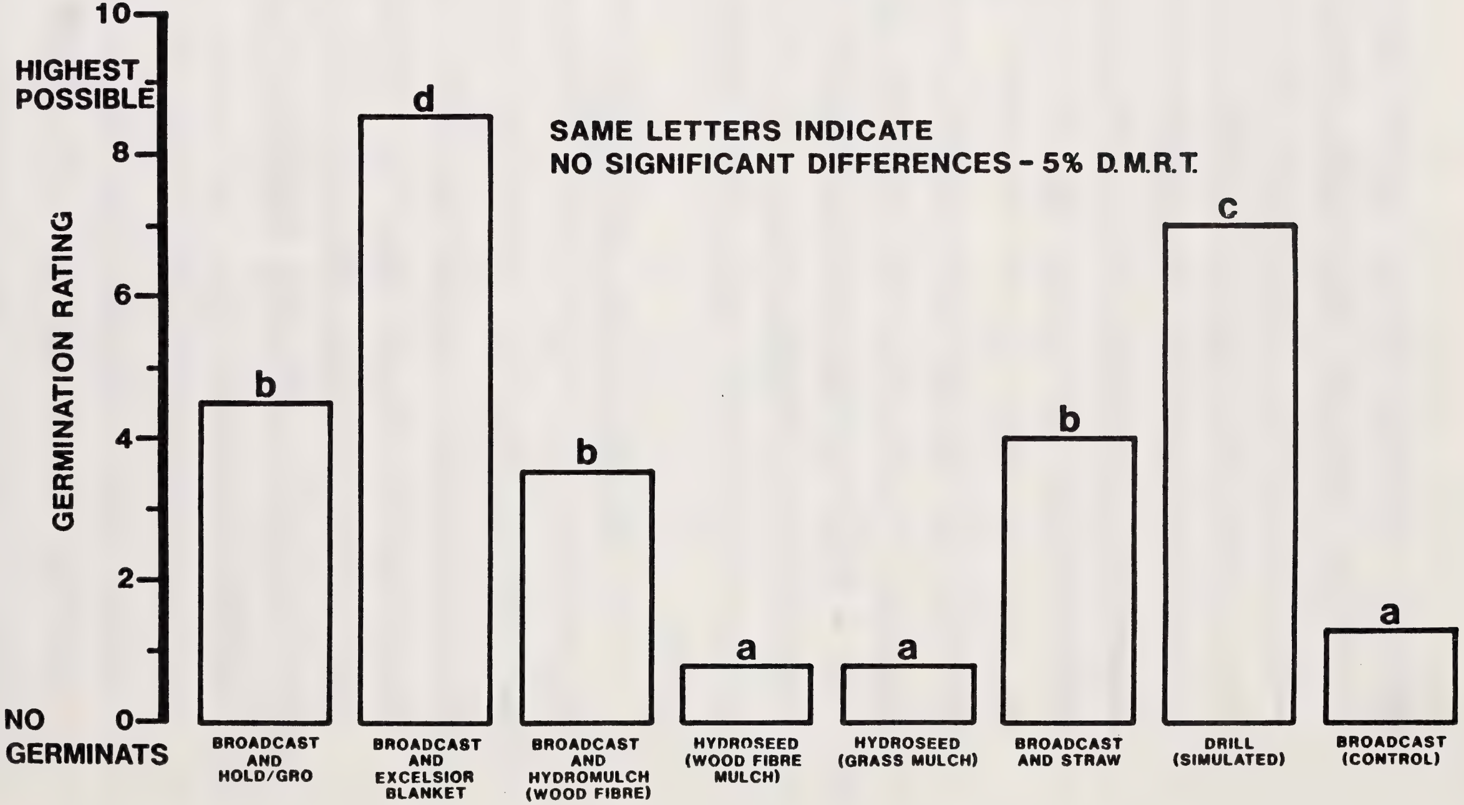
The high winds at this very exposed experimental site had a significant influence on the extent of the number of germinants in most of the treatments. Observation confirmed that the grass seeds were not adequately protected in some treatments and thus were lost in the wind. In the wood fibre mulch and grass mulch hydromulching, treatments to which tackifying agents were added, it was noticed that as the materials dried up, pieces or lumps were dislodged in the high-velocity gusts, resulting in seed losses.

As had been expected, based on observations from earlier experiments, plant cover at the end of the second growing season was low as compared with agronomic grass sown at the same mine two years earlier.

Figure 7:

NATIVE GRASS MIX GERMINATION RATINGS
EARLY IN THE SECOND GROWING SEASON - 1981

RATING: 0 (NO GERMINANTS) THROUGH 9 (HIGHEST GERMINANTS POSSIBLE)



SAME LETTERS INDICATE
NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.

Percentage of plant cover was best with the placement of straw or excelsior blanket after seed broadcast, and with simulated drilling (Figure 8). These three treatments provided the best protection from seed loss through the high winds on the site. The low percentage of plant cover with hold/gro suggested seed loss was considerably higher than expected as openings in the material allowed the wind to dislodge the seed. All other treatments produced poor plant cover, primarily because of the loss of the protective material (wood fibre or grass mulch) and seed to the high winds. The plant densities in Figure 9 partly support the seed loss argument. Other factors such as moisture and temperature differences in the seed beds brought about by the treatments also accounted for the different levels of seed germination. The relatively-low density count in the simulated drilling (Figure 9) suggests that the 2 cm seeding depth was not adequate to prevent the loss of smaller seeds (three species) to the high winds or that the drilling was too deep for germination of these small seeds. This question of depth of seeding small native grass seeds requires further study.

Density counts ratios by species given in Figure 10 for the treatments which produced the best plant cover and broadcast seeding (control) indicate that although the same numbers of seeds per species were in the seeded mix, the seed size played an important role in the actual counts as shown also in Table 4. Densities under the excelsior blanket treatment indicate that where a good mixture of native grasses of different seed sizes is preferred, this treatment is the best for at least the very harsh sites. There is a definite need to undertake further

Figure 8: NATIVE GRASS PLANT COVER
AT THE END OF THE SECOND (1981) GROWING SEASON

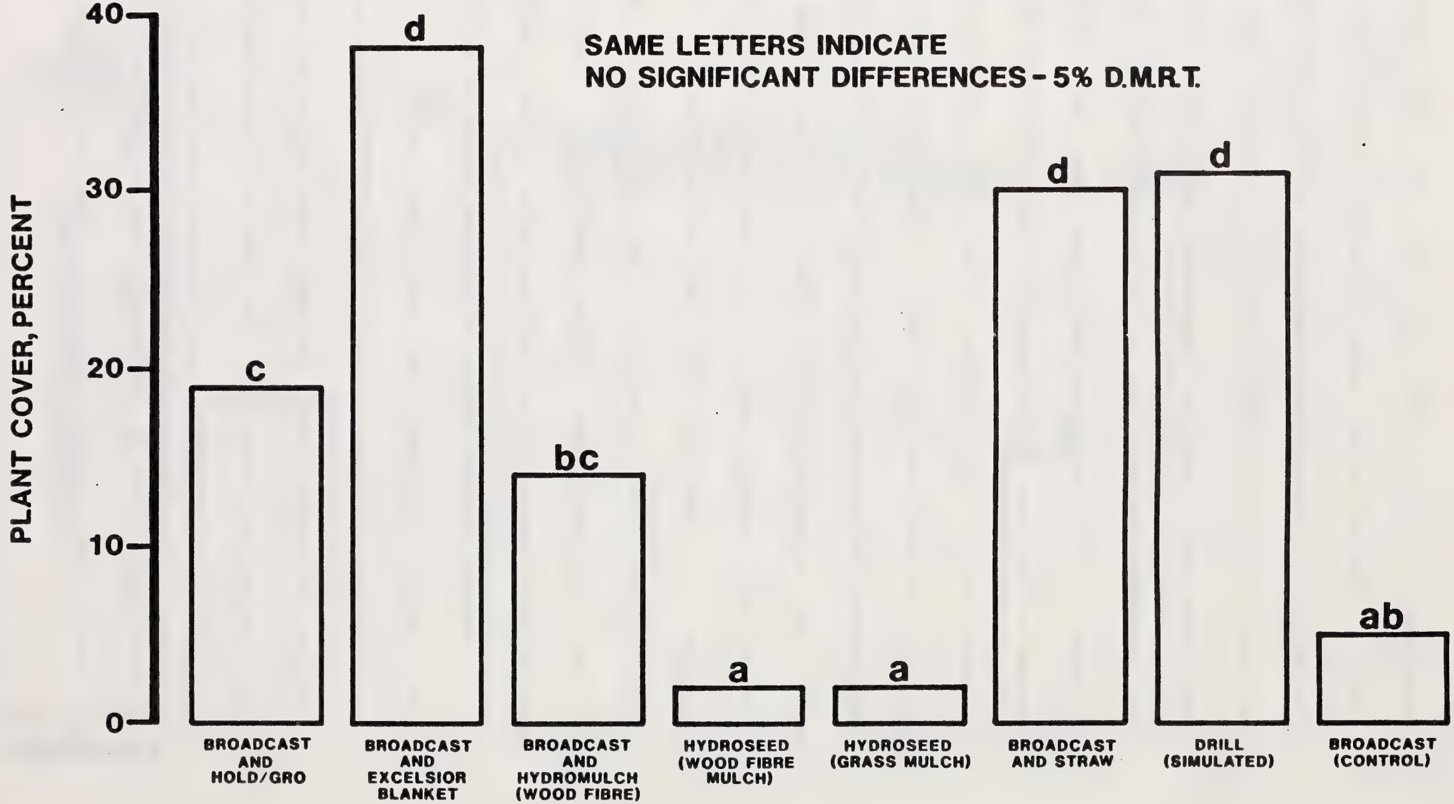
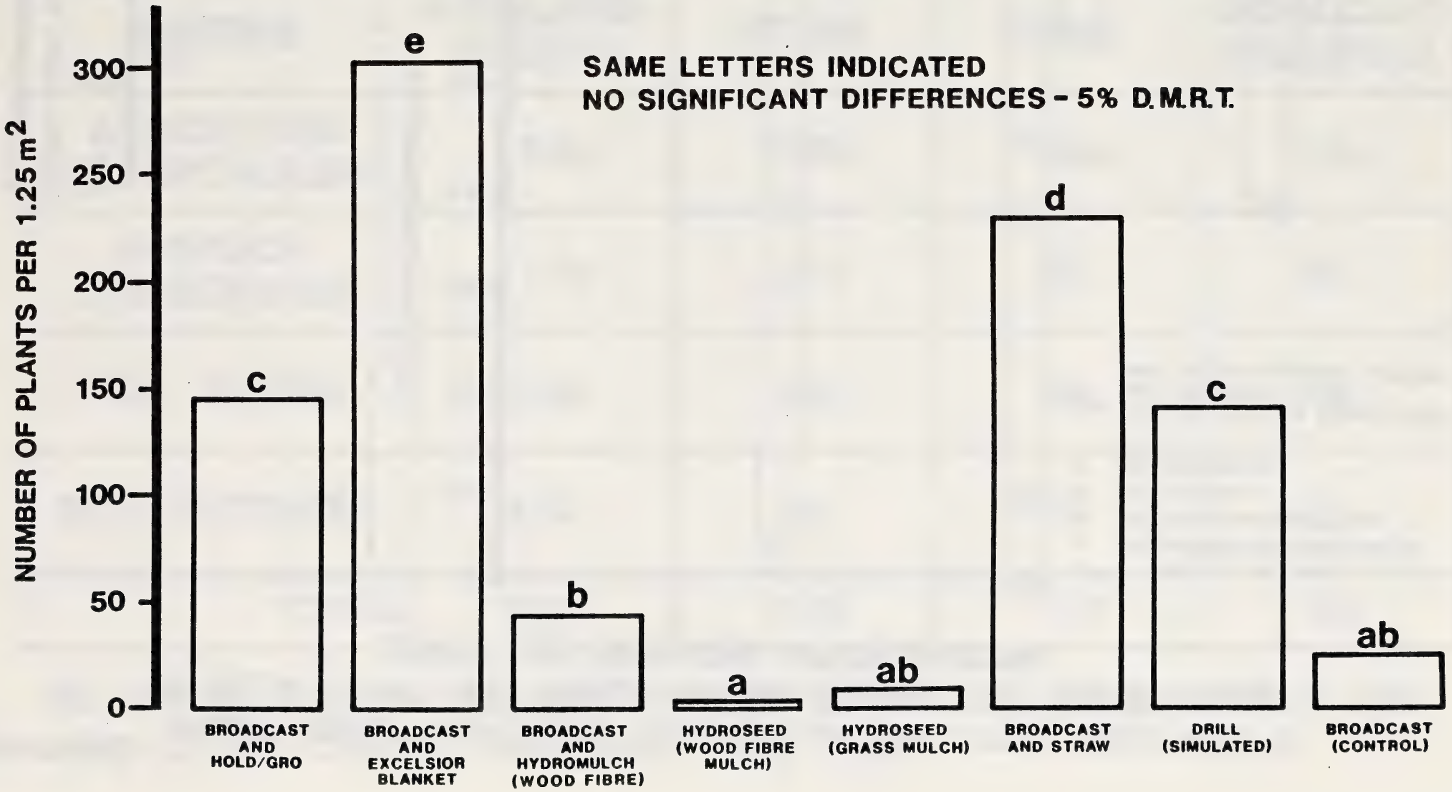

SAME LETTERS INDICATE
NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.

Figure 9: NATIVE GRASS PLANT DENSITIES AT THE END OF THE SECOND (1981) GROWING SEASON



SAME LETTERS INDICATED NO SIGNIFICANT DIFFERENCES - 5% D.M.R.T.

Figure 10: PLANT DENSITY RATIOS BY SPECIES IN SELECTED TREATMENTS IN RELATION TO THE RATIOS OF THE WEIGHTS OF THE SPECIES SOWN TWO SEASONS AFTER SEEDING

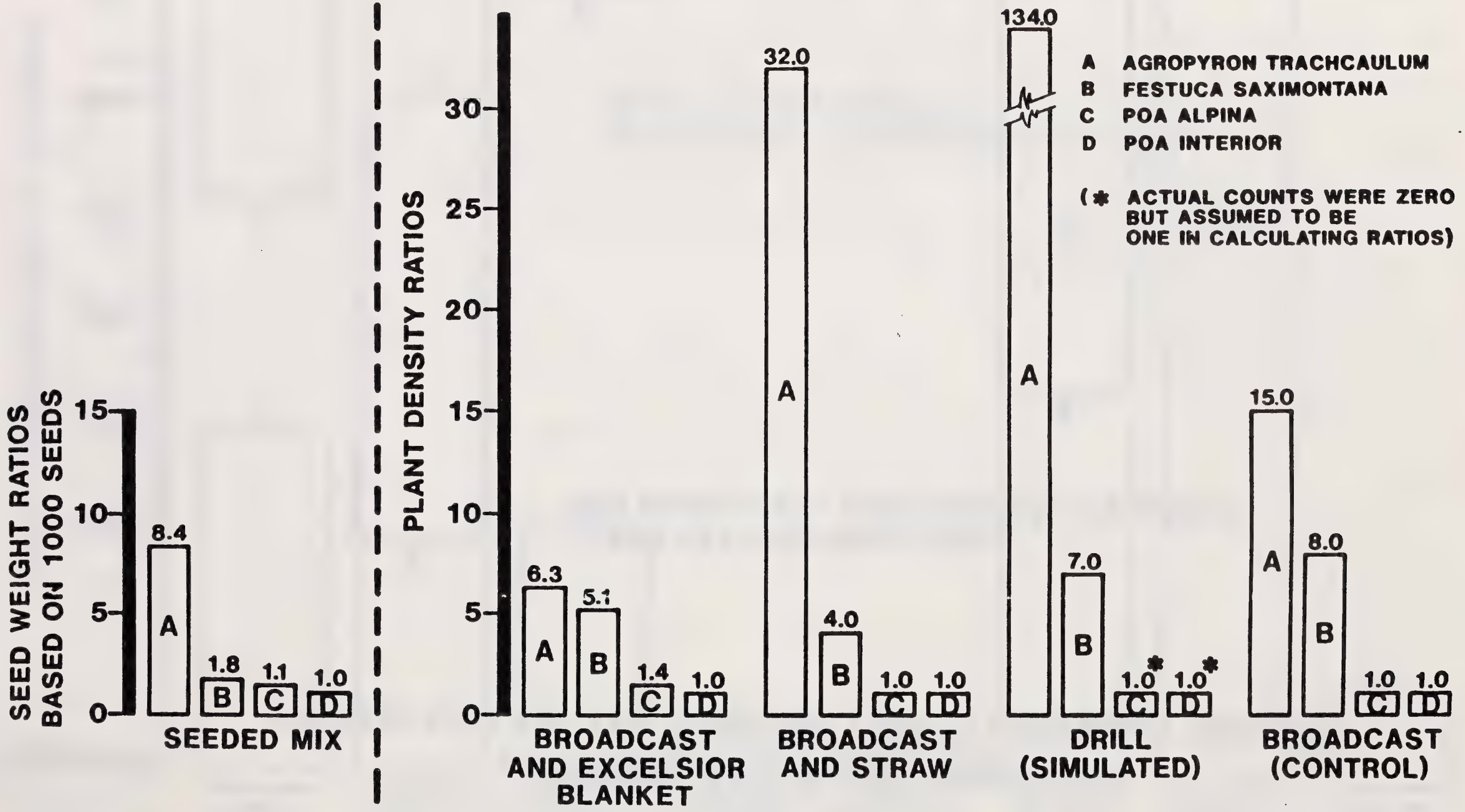


TABLE 4

PLANT DENSITIES IN THE THREE TREATMENTS PROVIDING THE BEST PERCENT COVER AND BROADCAST SEEDING - # OF PLANTS/1.25 m^2 (SECOND GROWING SEASON)

SPECIES	EXCELSIOR BLANKET	STRAW	DRILL	BROADCAST (CONTROL)
AGROPYRON TRACHCAULUM	138b	192b	134b	15c
FESTUCA SAXIMONTANA	112b	24a	7a	8b
POA ALPINA	31a	6a	0a	1a
POA INTERIOR	22a	6a	0a	1a
TOTAL	303	228	141	25

MEANS IN A GIVEN COLUMN FOLLOWED BY THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT - 5% D.M.R.T.

studies to identify seed mixture ratios which will ensure good mixed stands of native grasses. In this experiment, the Agropyron was the dominant species on this harsh site; in other situations, other desirable species such as F. saximontana or a balanced grass cover may be preferred.

CONCLUSIONS

As stated earlier, plant cover is recognized as the important component for the determination of adequate reclamation of disturbed land, especially in erosion problem areas. Its successful establishment is an important objective in the studies reported here. One underlying objective of the studies is that the recommended methods of cover establishment on drastically disturbed sites difficult to revegetate be practical for operational conditions, and at the same time impose very little or no cost restriction to the operation. Results of these studies, which did not analyse the costs involved, indicate that revegetation of harsh sites in the alpine and subalpine areas of the Rockies in Alberta is possible with the appropriate choice of cover establishment technique for both cultivated grasses and legumes, and native grass seed mixtures.

Results obtained have emphasized the ameliorative effects of the materials used in establishing cover on harsh sites, especially in the study with native grass mixtures. It has been demonstrated that certain techniques are essential to improve conditions on the harsh sites to a minimum level to achieve plant cover establishment and support plant growth. Through the choice of an appropriate establishment method native grasses of alpine and subalpine origins in appropriate seed mixtures can be successfully established on high-elevation severe-disturbance sites in Alberta. Because of the length of the growing season, acceptable ground cover cannot be achieved in the first year of seeding. There is certainly the need to develop appropriate native grass mixtures to ensure some diversity in species on a site to be reclaimed with native grasses. The seeding methods studied here have clearly shown that in native grass seed mixtures composed of species with seeds of considerable seed-size differences, conditions created in the seedbed favoured dominance by the large-seeded grass species. Hydroseeding with a wood fibre or grass mulch was not as effective on this site with high winds as methods involving the physical anchoring down of a protective material such as excelsior blanket or straw.

In the use of techniques of erosion control in cover establishment with cultivated grasses and legumes, results indicated that acceptable plant cover could be achieved in the season of sowing; the degree varied with the technique. Percentage of plant cover achieved in the first season was best in the mulches, especially hold/gro and excelsior blanket. Each of the establishment techniques employed was effective in controlling the little erosion which occurred as compared with a control, but none was effective in preventing spoil-bearing water that was flowing downslope from burying the material and the vegetation, as was the case in the single largest storm in the first growing season. The same was true with ridge construction across the slope. The possible exception was the excelsior blanket.

The high percentage of plant cover and dry matter production with hold/gro in the first season are attributable to the "greenhouse micro-environment" effect, the result of a restricted warm air flow under the material which is supported by the plants beneath. Under harsh site conditions, and especially in northern environments where the growing season is short and seeding could be as late as early summer, hold/gro is a promising material for achieving earlier growth, especially of the slower plant species. While the materials used proved effective in a situation of normal erosion problems, the data collected indicated that moisture conservation in the spoil was enhanced even in the pervious material. The effects of the materials on spoil temperatures suggested that it is possible to effect earlier seed emergence in late spring when frosts are frequent in the area, as the surface soil may not freeze so readily and therefore the surface temperatures may not fluctuate widely between days and nights.

The two studies covered in this paper are now in a monitoring phase. Maintenance fertilization has been withdrawn in one study for two seasons and in the other, starting this season. Data are being collected primarily in plant cover changes, biomass production, changes in nutrient levels in the spoil and overburden, and the biomass. These will be reported in due course.

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